28

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National Aeronautics
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SUMMARY

Noise and economic characteristics were obtained for an advanced supersonic transport concept that utilized wing-body blending, a double-bypass variable-cycle engine, superplastically formed and diffusion-bonded titanium in both the primary and secondary structure, and an alternative interior arrangement that provides increased seating capacity. The configuration has a cruise Mach number of 2.62, provisions for 290 passengers, a mission range of 8.19 Mm (4423 n.mi.), and an average operating cruise lift-drag ratio of 9.23.

Advanced operating procedures, which have the potential to reduce airport-community noise, were explored by using a simulator. Traded jet noise levels of 105.7 and 103.4 EPNdB were obtained by using standard and advanced takeoff operational procedures, respectively. A new method for predicting lateral attenuation was utilized in obtaining these jet noise levels. Therefore, if jet noise is considered representative of total noise, it appears that a supersonic transport could achieve the noise levels required by Federal Aviation Regulations, part 36, stage 2. Direct and total operating costs were calculated. Total operating cost of approximately 5.5 cents/passenger-km (10 cents/passenger-n.mi.) and a fuel efficiency of 16.4 seat-km/L (33.6 seat-n.mi./gal) were predicted for the design range and a load factor of 100 percent.

INTRODUCTION

The current high ticket price for a supersonic crossing of the Atlantic clearly points to the need for technical breakthroughs in order for future supersonic transports to be cost-effective. Over the last decade, both industry and NASA have conducted several advanced supersonic technology integration studies to evaluate the potential of significant advances in various disciplines (refs. 1 to 7). A successful supersonic transport would have to be acceptable both economically and environmentally. The most critical environmental issue facing supersonic aircraft is community sensitivity to airport noise. At the present time, a Federal Aviation Noise Regulation has not been adopted for supersonic aircraft. It is anticipated, however, that the communities would resist any exceptions to the subsonic regulations.

For several years, government and industry have conducted research in order to develop an understanding of jet noise, concepts for its reduction, and practical means for suppressor implementation. Coannular nozzles, mechanical suppressors, and thermal acoustic shields have been explored as part of the effort to reduce the noise of supersonic transports (refs. 8 to 10). Advanced aircraft operating procedures offer yet another means of reducing airport-community noise (refs. 11 and 12). The advanced takeoff procedures involve automated thrust modulation after lift-off and during climbout and a reduction in thrust levels below those presently allowed. The advanced landing procedures involve decelerating approaches and constant glide slopes.

The Langley Visual/Motion Simulator (ref. 12) and a NASA Aircraft Noise Prediction Program (ref. 13) were utilized in order to evaluate the noise characteristics of an advanced supersonic transport concept by using standard and advanced operational procedures.

A significant factor affecting the community noise around airports is the lateral attenuation of aircraft noise. Recently, the Society of Automotive Engineers (SAE) Aircraft Noise Committee has collected all the available data on lateral attenuation of aircraft noise and has developed a new method for its prediction during takeoff and landing (ref. 14). This method has been used in predicting the noise characteristics of the subject configuration and the results are compared with the Chien-Soroka method (ref. 15), which has previously been the generally accepted standard method for predicting lateral attenuation.

An airline evaluates the profit-making potential of any aircraft which it considers for incorporation into its fleet. Direct and total operating costs are important parameters in determining the profit-making capability of any aircraft. Estimates of these costs were calculated as a function of range and load factor for the advanced transport configuration addressed in this study.

The purpose of this report is to document the predicted noise and economic characteristics of an advanced supersonic transport concept and assess advanced operating procedures for noise control.

SYMBOLS

EPNL	effective perceived noise level, dB
IAS	indicated airspeed
M	Mach number
V	airspeed, knots
V_C	climb speed, knots
V_R	aircraft velocity at rotation, knots
V_2	aircraft velocity at obstacle, knots
γ	flight-path angle, deg
δ_f	trailing-edge flap deflection, deg

CONFIGURATION DESCRIPTION

The supersonic transport concept used in this study is documented in detail in references 16 and 17. Advanced level technology items included in this concept consisted of wing-body blending, a double-bypass variable-cycle engine, superplastically formed and diffusion-bonded titanium in both the primary and secondary structures, and an alternative interior arrangement that provides increased seating capacity.

Designed for a cruise Mach number of 2.62 and a mission range of 8.19 Mm (4423 n.mi.), the configuration has an average operating cruise lift-drag ratio of 9.23 and could accommodate 290 passengers. Aerodynamic performance up to a Mach number of 1.7 was based on values derived from an existing data base on similar configurations. High-speed aerodynamic performance for Mach numbers from 1.7 to 2.7 was derived from recent tests in the Langley Unitary Plan Wind Tunnel on blended wing-fuselage configurations.

Technology projected to be available in 1985 was encompassed in the double-bypass variable-cycle engine. The engine has a design overall pressure ratio of 13.5, a bypass ratio of 0.25, and a low-temperature (1331 K) augmenter. The inlet is an axisymmetric, mixed compression design with a translating centerbody. The exhaust system consists of an inverted velocity profile, coannular translating plug with a 20-shallow-chute mechanical sound suppressor in the outer stream. Based on model-scale free-jet experiments, the suppressor is expected to provide 4 EPNdB of suppression at all conditions (ref. 18).

An improved version of the computer program of reference 19 was used for the sizing, configuration selection, and determination of mission performance characteristics. A sketch of the configuration and pertinent characteristics are presented in figure 1 and table I, respectively. Principal design characteristics of the configuration are a takeoff gross weight of 2.85 MN (640 000 lbf); a sea-level-static installed thrust-weight ratio of 0.30; and a wing loading of 3.64 kPa (76 lbf/ft^2).

TESTS AND PROCEDURES

Simulator Description

Studies of the noise resulting from standard and advanced takeoff and landing procedures were made by using the general-purpose cockpit of the Langley Visual/Motion Simulator (VMS). The VMS is a ground-based motion simulator with six degrees of freedom. For this study, it had a transport-type cockpit which was equipped with conventional flight and engine-thrust controls and with a flight instrument display representative of those found in current transports (fig. 2). Control forces on the wheel, column, and rudder pedals were provided by a hydraulic system coupled with an analog computer. The system allows for the usual variable-feel characteristics of stiffness, damping, coulomb friction, breakout forces, detents, and inertia. A more detailed description of the simulator is documented in reference 12. A constant weight of 2.85 MN (640 000 lbf) and 1.71 MN (384 665 lbf) was used for takeoff and landing, respectively.

Operating Procedures

The term "standard procedures" refers to those procedures that adhere to all present Federal Aviation Regulations, whereas the term "advanced procedures" refers to procedures that do not adhere to all the regulations required by aircraft noise certification rules. Two standard and four advanced takeoff procedures were investigated. Table II presents the aircraft velocity at rotation, climb speeds, thrust cutback levels, autothrottle usage, and trailing-edge flap deflection for the standard and advanced operating procedures. In order to evaluate the flight safety of the advanced procedures, an engineer test pilot participated in the simulation program.

Standard takeoff procedures.- The piloting procedures used for the standard case were as follows:

Accelerate from brake release to V_R

At V_R, rotate the airplane at an angular rotation rate of 3 deg/sec to an initial angle of attack and maintain that angle until V_2 is achieved

After attaining V_2, accelerate to and maintain climb speed at either $V_2 + 10 = 223$ knots (IAS) (standard procedure I) or 250 knots (IAS) (standard procedure II)

Upon attaining the designated cutback point 5.49 km (18 000 ft) from brake release, reduce the net thrust to a specified level as the climb gradient is reduced to 4 percent ($\gamma = 2.3°$)

Procedures used to determine the allowable minimum and maximum rotation speeds are defined in reference 20. A climb speed of $V_2 + 10$ knots (IAS) was used because it is the minimum required speed during takeoff noise tests, and a climb speed of 250 knots (IAS) was used because it is the maximum allowed speed below an altitude of 3.05 km (10 000 ft). The amount of allowable thrust cutback was limited to the criterion of reference 21, which states that takeoff thrust may not be reduced below that needed to maintain level flight with three engines operating (one engine inoperative) or to maintain a 4-percent climb gradient with four engines operating, whichever power or thrust is greater. Figure 3 presents the allowable thrust cutbacks for these two conditions. The three-engine-operating, zero-climb gradient requires the highest thrust level and, therefore, was used to determine the allowable thrust cutback levels of 60 percent and 53 percent for the climb speeds of $V_2 + 10 = 223$ and 250 knots, respectively.

Advanced takeoff procedures.- The regulations that were subject to deviation during the advanced procedure study are as follows:

A constant takeoff configuration must be maintained throughout the takeoff noise test, except that the landing gear may be retracted

Takeoff power or thrust must be used from the start of takeoff roll to an altitude above the runway of at least 213 m (700 ft)

Upon reaching an altitude of 213 m (700 ft) or greater, the takeoff power or thrust may not be reduced below that needed to maintain level flight with one engine inoperative or to maintain a 4-percent climb gradient with four engines operating, whichever power or thrust is greater

The advanced takeoff procedures used in this study to evaluate minimum flyover EPNL's are designated advanced procedures I and II. Advanced procedures I and II are similar to standard procedures I and II, respectively, except that the autothrottle, which was activated at the flyover cutback point, was used to maintain the desired climb speeds. The advanced procedures used in this study to evaluate minimum sideline EPNL's are designated advanced procedures III and IV. For advanced procedures III and IV, net thrust was reduced to approximately 84 percent after attaining V_2, and the autothrottle was activated at the flyover cutback point; for advanced procedure VI, the flaps were raised to 10° after attaining V_2. For these four advanced procedures, the net thrust levels after the flyover cutback point were momentarily below the FAR-36 specifications (ref. 21); however, climb-speed and climb-gradient specifications were satisfied.

Landing approaches.- Reference 20 states that a constant airspeed, constant configuration, and constant glide angle (3° ± 0.5°) must be maintained throughout the landing approach noise test. During this simulation study, landing approaches were made at a constant speed of 156 knots (IAS) on a constant 3° glide angle (standard procedure), and a decelerating speed on a constant 3° glide angle (advanced procedure). For the decelerating approach, the airspeed varied from 200 knots (IAS) smoothly down to 156 knots (IAS). The deceleration was initiated at the outer marker (approximately 8149 m (26 735 ft) from the runway threshold) and was completed at the noise measuring station shown in figure 4. It should be noted that speed brakes were used during the simulated decelerating approaches.

RESULTS AND DISCUSSION

Noise Characteristics

Noise prediction methods.- By using the takeoff and landing profiles generated with the simulator, the noise characteristics of the subject configuration were calculated at the three measuring stations prescribed in reference 21 and indicated in figure 4. Noise predictions were made with a NASA Aircraft Noise Prediction Program (ANOPP). (See ref. 13.) This program uses time-dependent trajectory and engine data to predict the time-dependent one-third-octave-band spectra at a set of observer positions. These spectra are then integrated to obtain effective perceived noise levels.

The program includes noise prediction modules for jet mixing, jet shock-cell, fan, core, turbine, and airframe noise. Total noise was calculated in terms of effective perceived noise level. The methodology used in this program has been adopted by the International Civil Aviation Organizations (ICAO) Civil Aircraft Noise Committee as a "Reference Prediction Procedure" and has served as a common denominator for parametric studies and noise calculations carried out for the Committee. It should be noted, however, that further research is required and is underway to more accurately predict shock-cell, fan, and turbine noise (ref. 13). In addition, variable-cycle engine concepts allow for tailoring the inlet and exhaust flows, and if these characteristics are utilized properly, fan and shock-cell noise could be markedly reduced (ref. 22) and jet-only noise would be representative of the total noise. Therefore, the discussion of noise levels for the subject configuration will primarily be based on the jet-only noise data.

A significant factor in calculating the community noise exposure around airports is the lateral attenuation of aircraft noise. Until recently, the only large data base available was ground-to-ground propagation data (ref. 23); there were very little air-to-ground data available. The Chien-Soroka method (ref. 15), which has been the standard for predicting lateral attenuation, was developed based on these data. Recently, a series of flight tests were conducted in order to obtain needed air-to-ground data (refs. 24 and 25). The Society of Automotive Engineers (SAE) Aircraft Noise Committee has collected these results along with other available data on lateral attenuation of aircraft noise and developed a new prediction method (ref. 14). This method has been used in predicting the noise characteristics of the subject configuration and the results are compared with noise levels obtained with the Chien-Soroka method.

Noise levels.- Figure 5 shows the thrust, airspeed, and altitude as a function of distance from brake release for the standard and advanced takeoff procedures that were flown with the simulator and the sideline and flyover jet noise levels resulting from these procedures. It can be seen that the sideline noise levels obtained with the SAE lateral attenuation method are approximately 4 to 6 EPNdB lower than those obtained with the Chien-Soroka method. For the slower takeoffs, the altitude over the flyover monitor was higher and consequently the flyover noise was approximately 2 EPNdB lower. Compared with the standard takeoff procedures (fig. 5(a)), net thrust reductions below those allowed by FAR-36 specifications at the flyover cutback point resulted in lower flyover noise levels (fig. 5(b)), and this procedure coupled with net thrust reductions after attaining V_2 resulted in reduced flyover and sideline noise (fig. 5(c)).

A comparison of the takeoff noise levels for the various procedures is shown in table III. Total noise (all sources) and jet noise only are shown. Differences between the total noise and jet noise only range from 2.6 to 4.8 EPNdB for flyover noise and from 1.1 to 2.1 EPNdB for sideline noise, depending on the takeoff procedure. A comparison of the results for standard procedure I and advanced procedure III shows that advanced operating procedures could result in reductions of approximately 3 EPNdB and 2 EPNdB in flyover and sideline jet noise, respectively. It should be noted that if only jet noise is considered and lateral attenuation is predicted by the SAE method, standard procedure I and all the advanced takeoff procedures meet the FAR-36 stage-2 takeoff noise requirement of 108 EPNdB.

The standard landing approach EPNL (from all sources) calculated for a constant indicated airspeed of 156 knots, a constant configuration, and a constant glide angle of 3° was 109.2 dB at the measuring station, which is 2000 m (6562 ft) from the threshold, on the extended centerline of the runway. (See fig. 4.) However, the total approach noise minus the noise contribution of the fan was calculated to be 101.9 EPNdB. Therefore, indications are that if fan noise is markedly reduced, the approach noise, using standard procedures, would meet the FAR-36 stage-2 requirement of 108 EPNdB.

When the airplane was decelerated from 200 to 156 knots (IAS), the calculated approach jet noise was 2.5 EPNdB less than when the airplane was flown at a constant speed of 156 knots (IAS) with a constant configuration (speed brakes were not used). Time histories of thrust indicate that, at distances from the runway threshold greater than the noise measuring station, less thrust was required for the decelerating approach than for the standard approach; this indicates that the areas of the landing approach noise contours would be reduced.

Noise trade-offs and contours.- The FAR-36 noise standards dictate a maximum EPNL limit at the sideline, flyover, and approach noise measuring stations for airplanes as a function of gross weight. However, trade-offs are allowed among the three noise components. The rule is as follows: The sum of the traded EPNL's cannot be greater than 3 dB; no more than 2 dB may be traded from any one component; and the total noise level reductions in the selected component or components must be traded (offset) by equal additions in the remaining component or components. The traded noise level is the highest component noise level after the trades are completed.

Figure 6 presents, for the two methods of calculating lateral attenuation, the traded jet noise levels for standard takeoff procedure I and advanced takeoff procedure III, with standard procedures used for landing approach. With the SAE lateral attenuation method, traded jet noise levels for standard takeoff procedures and advanced takeoff procedure III were 105.7 and 103.4 EPNdB, respectively. Therefore, if jet noise is considered representative of the total noise, it appears that a supersonic transport could achieve the noise levels required by FAR-36, stage 2.

A noise contour represents the boundary of the area enclosing effective perceived noise levels equal to or greater than the specified contour level. Noise contours were determined for the takeoffs and landings simulated during the present study in order to indicate the noise-reduction advantages of using operational procedures other than standard. The areas of the calculated contours are indicated in table IV and takeoff EPNL contour plots are presented in figure 7 for standard procedure I and advanced procedure III. The noise contour areas, which were predicted by the ANOPP program, are based on jet noise only and the SAE lateral attenuation method for calculating sideline noise.

As indicated in table IV, advanced takeoff procedures III and IV reduced the 104 EPNdB contour areas of the takeoff standard procedure I by approximately 50 percent. Table IV also indicates that the decelerating approach reduced the 96 EPNdB contour area of the standard approach by more than 70 percent. However, contour areas are very sensitive to noise level prediction errors. For example, an error of 2 dB in the prediction of an EPNL contour of 110 dB would result in a 46-percent error in contour area. Since the same method (ANOPP) was used for predicting the noise levels for the standard and advanced procedures, it is believed that the difference in noise contour areas reflect the relative benefits of advanced operating procedures in reducing the effective perceived noise levels in the airport community.

Flight Safety

In order to evaluate the effect of the advanced procedures on flight safety, an outboard engine was failed at various locations during both takeoff and landing. It was the opinion of the engineer test pilot that the advanced procedures posed no safety problems. In addition, the test results indicated that for an engine failure above a speed of 230 knots (IAS), one could have safely chosen to continue to follow the noise-abatement flight profile instead of following a flight profile dictated by an emergency situation. This result was attributed to the excess climb thrust available on the simulated transport.

Economic Characteristics

An airline evaluates the economic viability of any aircraft which it considers for incorporation into its fleet. Direct and total operating costs are important parameters in determining the profit-making capability. Fuel cost is the largest single factor in the total operating costs for a particular mission.

Fuel usage for the subject configuration was determined by use of an improved version of the computer program discussed in reference 19. Baseline aerodynamic characteristics, propulsion, and weight data were required as input to the program. The primary cruise leg was flown at the altitude for best Breguet range factor. Fuel reserves were based on the requirements of reference 26. A matrix of hold altitudes and Mach numbers were evaluated to determine an optimum hold condition. The results of the analysis indicate that the best hold condition was at $M = 0.8$ at 10-km (32 849-ft) altitude. Subsonic cruise to the alternate airport was done at the altitude and speed that resulted in the best Breguet factor. A mission profile and the fuel weights associated with each segment are shown in figure 8. The block fuel used for the 8191-km (4423-n.mi.) mission was 1.137 MN (255 595 lbf). Seat-kilometers per liter (seat-nautical miles per gallon), which is an indication of fuel efficiency, was 16.4 (33.6) for the subject configuration.

Direct operating cost was calculated by using the Air Transport Association method described in reference 27, and the indirect operating cost was calculated in accordance with the method described in reference 28. Direct operating cost is made up of the following elements: crew, fuel, insurance, maintenance, and depreciation. Indirect operating cost includes general and administrative, landing fees and servicing, cabin attendants, food, passenger handling, and advertising. Total operating cost is the sum of the direct and indirect operating costs. Table V presents the input factors used to calculate these costs. The cost figures are in 1980 dollars except for fuel. The fuel cost of 53 cents/L (2.00 dollars/gal) is based on 26.5 cents/L (1.00 dollar/gal) for a 1980 base and the cost is escalated at an assumed rate of 3.5 percent/year above inflation to the year 2000. It should also be noted that the airframe and engine costs are based on a production run of 300 aircraft.

Direct and total operating costs as a function of range are shown in figures 9 and 10, respectively, for load factors of 60 percent and 100 percent. The amount of direct operating costs applicable to fuel cost only is shown in figure 9. For a fuel price of 53 cents/L (2.00 dollars/gal) and a load factor of 100 percent, fuel amounts to approximately 84 percent of the direct operating cost. A total operating cost of approximately 5.5 cents/passenger-km (10 cents/passenger-n.mi.) was predicted for the design range of 8.19 Mm (4423 n.mi.) and a load factor of 100 percent. This level of total operating cost is in agreement with predictions made in reference 29.

Total operating cost does not include the interest paid on funds necessary to purchase the aircraft. A loan of 70 percent of the cost of the airplane at 12 percent interest amortized over 16 years was assumed and total cost, which is the sum of direct and indirect operating costs plus interest, was calculated. Sensitivity of the total cost to variations in fuel cost and hours of utilization for the mission range of 8.19 Mm (4423 n.mi.) is shown in figure 11. The utilization input used to develop the operating costs shown in the previous figures was 12 hours/day. It can be seen that total cost is much more sensitive to fuel price than it is to utilization.

CONCLUDING REMARKS

Noise and economic characteristics were obtained for an advanced supersonic transport that utilized wing-body blending, a double-bypass variable-cycle engine, superplastically formed and diffusion-bonded titanium in both primary and secondary structures, and an alternative interior arrangement that provides increased seating capacity. The study configuration has a range of 8.19 Mm (4423 n.mi.) with 290 passengers at a cruise Mach number of 2.62. Principal design characteristics were a takeoff gross weight of 2.85 MN (640 000 lbf), a thrust-weight ratio of 0.30, and a wing loading of 3.64 kPa (76 lbf/ft^2). The average operating lift-drag ratio during cruise was 9.23.

A piloted simulation study was conducted on this configuration in order to develop and evaluate operational procedures that have the potential to reduce airport-community noise during both takeoff and landing. One advanced takeoff procedure resulted in reductions of approximately 3 EPNdB in flyover jet noise and 2 EPNdB in sideline jet noise compared with the noise levels for a standard takeoff procedure. A decelerating approach speed resulted in a reduction of 2.5 EPNdB in approach noise compared with the noise level for a constant approach speed. Utilizing a standard landing approach procedure, traded jet noise levels of 105.7 and 103.4 EPNdB were obtained with standard and advanced takeoff operational procedures, respectively. These results were obtained with a new SAE method for predicting lateral attenuation which resulted in sideline noise levels 4 to 6 EPNdB lower than those predicted by the standard Chien-Soroka method. Therefore, if jet noise is considered representative of total noise, it appears that a supersonic transport could achieve the noise levels required for subsonic airplanes by Federal Aviation Regulation, part 36, stage 2.

The configuration was predicted to have a fuel efficiency of 16.4 seat-km/L (33.6 seat-n.mi./gal). For a fuel price of 53 cents/L (2.00 dollars/gal), fuel amounted to approximately 84 percent of the direct operating cost. A total operating cost of approximately 5.5 cents/passenger-km (10 cents/passenger-n.mi.) was predicted for the design range and a load factor of 100 percent.

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TABLE I.- AIRCRAFT CHARACTERISTICS

Takeoff gross weight, kN (lbf)	2846.86 (640 000)
Operating empty weight, kN (lbf)	1236.85 (278 054)
Payload:	
Passengers (290), kN (lbf)	212.85 (47 850)
Passenger baggage, kN (lbf)	56.76 (12 760)
Wing reference area, m^2 (ft^2)	784.75 (8447)
Aspect ratio based on wing reference area	1.9
Leading-edge sweep, deg	74.0, 70.8, and 60.0
Installed thrust-weight ratio	0.30
Wing loading, kPa (lbf/ft^2)	3.63 (75.8)
Sea-level-static[a] installed thrust per engine, kN (lbf)	213.5 (48 000)

[a]Standard + 10°C day.

TABLE II.- CONDITIONS FOR STANDARD AND ADVANCED TAKEOFF OPERATING PROCEDURES

Procedure	V_R, knots (IAS)	V_c, knots (IAS)	δ_f, deg	Minimum net thrust level after cutback, percent	Autothrottle
Standard I	185	$V_2 + 10 = 223$	20	[a]60	No
Standard II	200	250	20	[a]53	No
Advanced I	185	$V_2 + 10 = 223$	20	[a]51	Yes
Advanced II	200	250	20	[a]49	Yes
Advanced III	185	$V_2 + 10 = 223$	20	[b]84 [a]51	Yes
Advanced IV	200	250	20 raised to 10 at V_2	[b]84 [a]41	Yes

[a]Cutback point 5.49 km (18 000 ft) from brake release.
[b]Cutback point at V_2.

TABLE III.- EFFECTIVE PERCEIVED NOISE LEVELS FOR VARIOUS TAKEOFF PROCEDURES

Procedure	Flyover EPNdB		Sideline EPNdB			
			Chien-Soroka		SAE	
	All sources	Jet only	All sources	Jet only	All sources	Jet only
Standard I	110.3	[a]107.7	111.6	110.5	[a]107.5	[a]106.1
Standard II	112.4	109.7	111.8	110.5	[a]106.7	[a]105.6
Advanced I	[a]107.8	[a]104.1	111.9	110.6	[a]107.6	[a]106.4
Advanced II	110.3	[a]106.3	111.8	110.6	[a]106.6	[a]105.5
Advanced III	109.1	[a]104.8	111.2	109.3	[a]105.6	[a]103.8
Advanced IV	111.2	[a]106.4	110.3	108.5	[a]104.0	[a]101.9

[a]Meets takeoff FAR-36, stage-2 requirement (ref. 21).

TABLE IV.- EFFECT OF PILOTING PROCEDURE ON NOISE CONTOURS

[Jet noise only]

Procedure	EPNL Contour, dB	Area of contour	
		km^2	$n.mi.^2$
Takeoff			
Standard I	108 104	3.43 8.95	1.00 2.61
Standard II	108 104	3.40 5.87	0.99 1.71
Advanced I	108 104	3.22 4.94	0.94 1.44
Advanced II	108 104	3.40 5.18	0.99 1.51
Advanced III	108 104	2.92 4.56	0.85 1.33
Advanced IV	108 104	2.81 4.29	0.82 1.25
Approach			
Standard: constant speed and glide angle ...	100 96	0.120 0.974	0.035 0.284
Decelerating: V = 200 to 156 knots (IAS) on constant glide angle	100 96	 0.285	 0.083

TABLE V.- DIRECT-OPERATING-COST AND INDIRECT-OPERATING-COST INPUT FACTORS

[1980 costs (except fuel)]

Direct-operating-cost inputs:	
Flight profile	International with no subsonic cruise leg
Aircraft economic life, yr	16
Utilization, hr/yr	4380
Aircraft salvage value, percent of aircraft cost including spares	15.0
Insurance cost, percent of initial aircraft cost/yr	0.5
Interest rate, percent/yr	12.00
Labor (maintenance) rate, dollars/hr	13.00
Overhead (maintenance burden) rate, dollars/hr	2.0 × Labor rate
Ground maneuver time, min/flight	10
Passenger weight, including baggage, N (lb)	930 (209)
Cargo, N (lb)	Baggage only
Configuration layout	All tourist
Cabin attendants	1/40 seats
Fuel cost, Jet A, cents/L (dollars/gal)	53 (2.00)
Airframe spares, percent of airframe cost	6.0
Engine spares, percent of total engine cost	30.0
Nonrevenue factor, fuel and maintenance, percent	2.0
Airframe cost,[a] dollars/N (dollars/lb)	90 (400)
Engine cost,[a] dollars/N (dollars/lb)	108 (480)
Indirect-operating-cost coefficients:	
K_1, local plus system	8.62
K_2, airport control	115.22
K_3, cabin attendants	64.51
K_4, food	0.86
K_5, passenger handling	24.49
K_6, cargo handling	225.87
K_7, other services	0.0128
K_8, freight commission	0.0174
K_9, general and administrative	0.0373

[a]Based on production run of 300 aircraft including development cost.

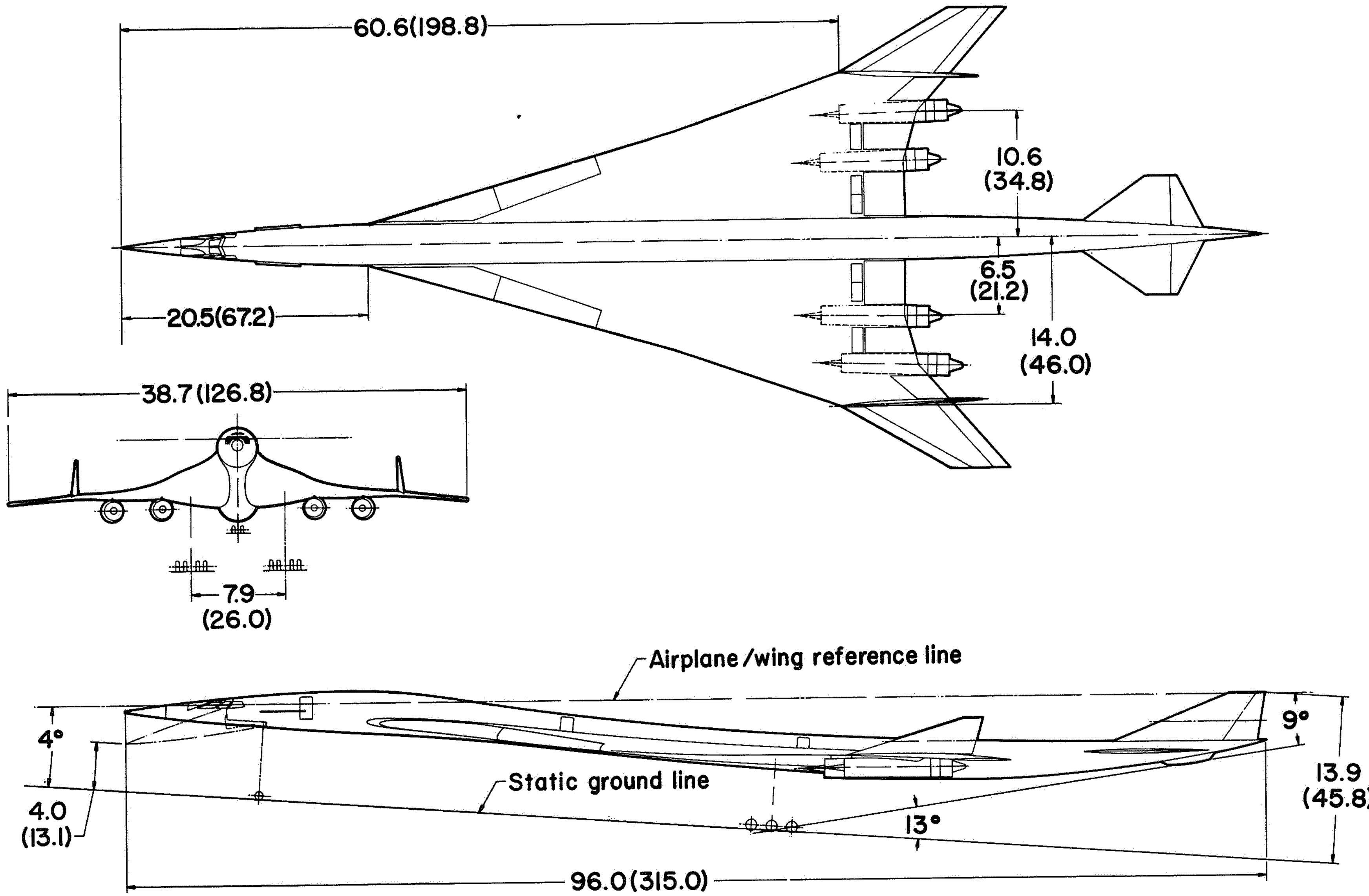

Figure 1.- General geometric characteristics of configuration. Linear dimensions are in meters (feet).

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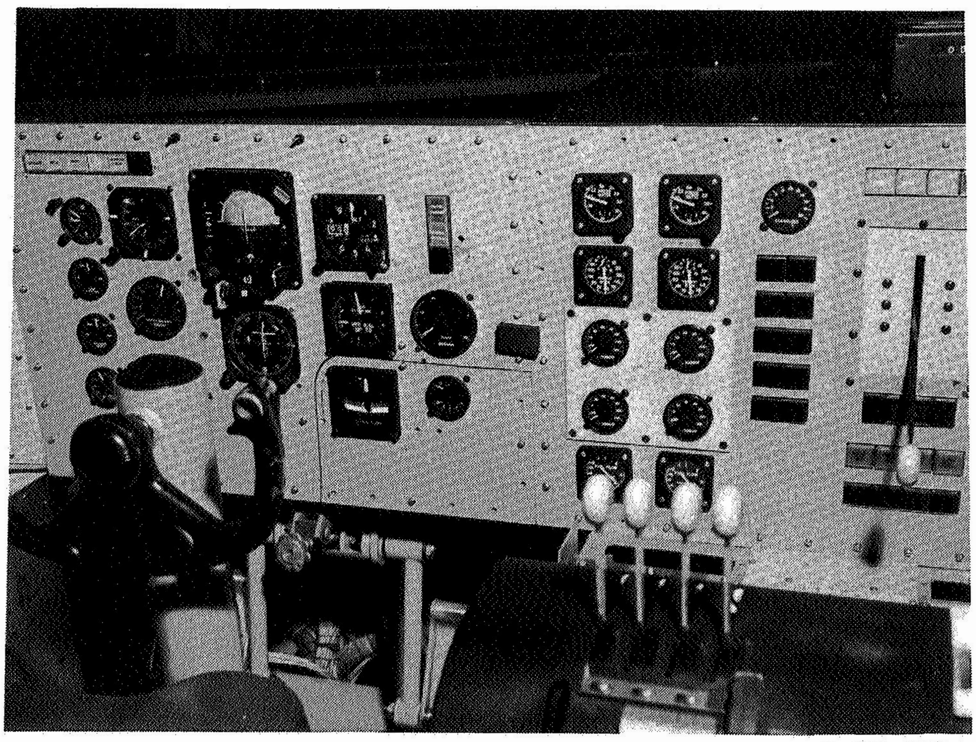
(a) Langley Visual/Motion Simulator.



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(b) Instrument panel.

Figure 2.- Langley Visual/Motion Simulator and instrument panel display.

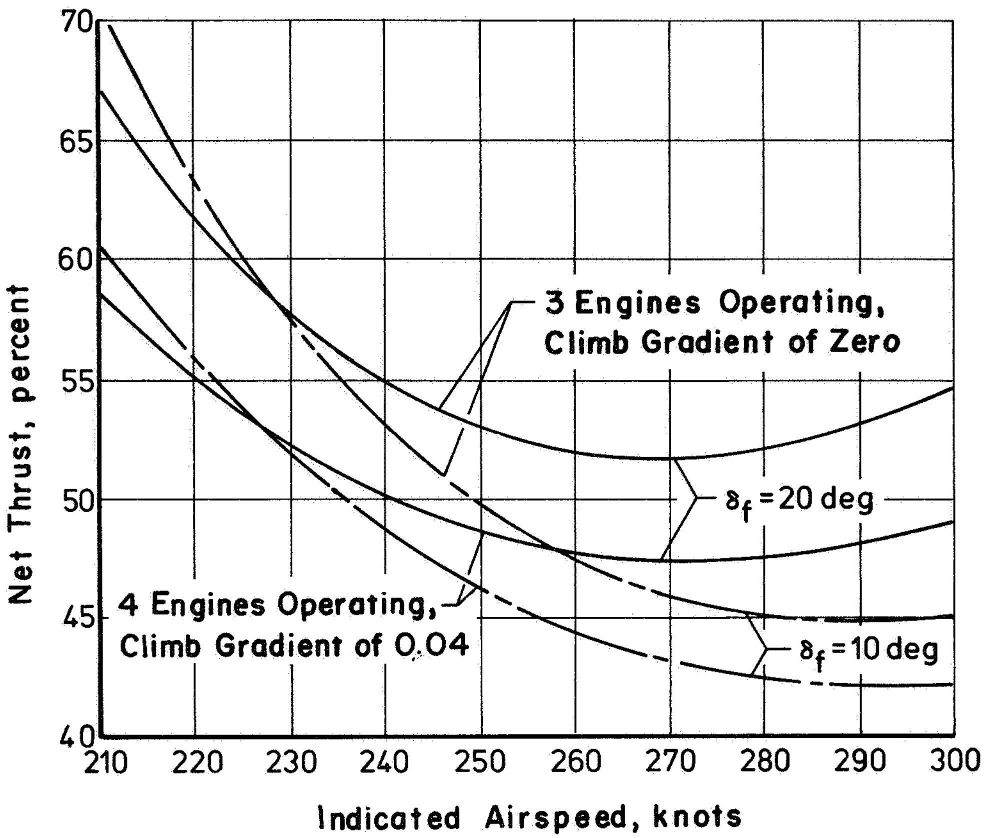


Figure 3.- Trimmed net thrust used in establishment of allowable thrust cutback.

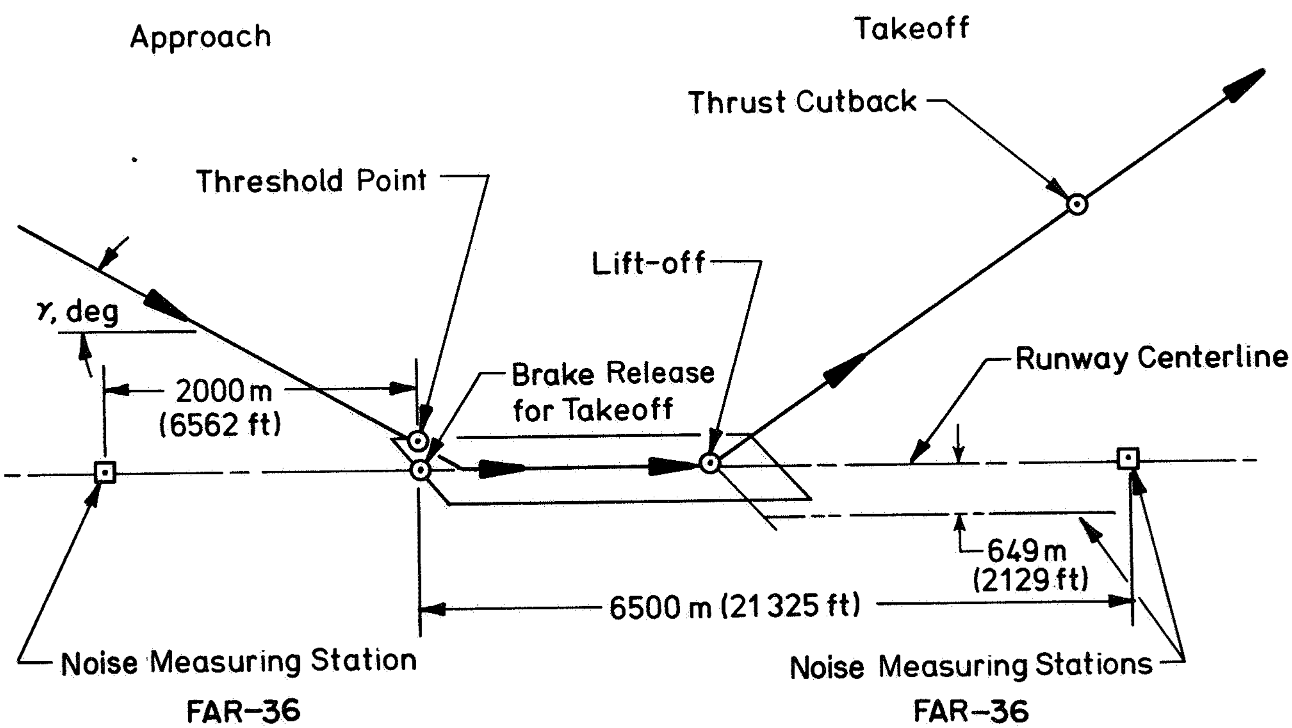
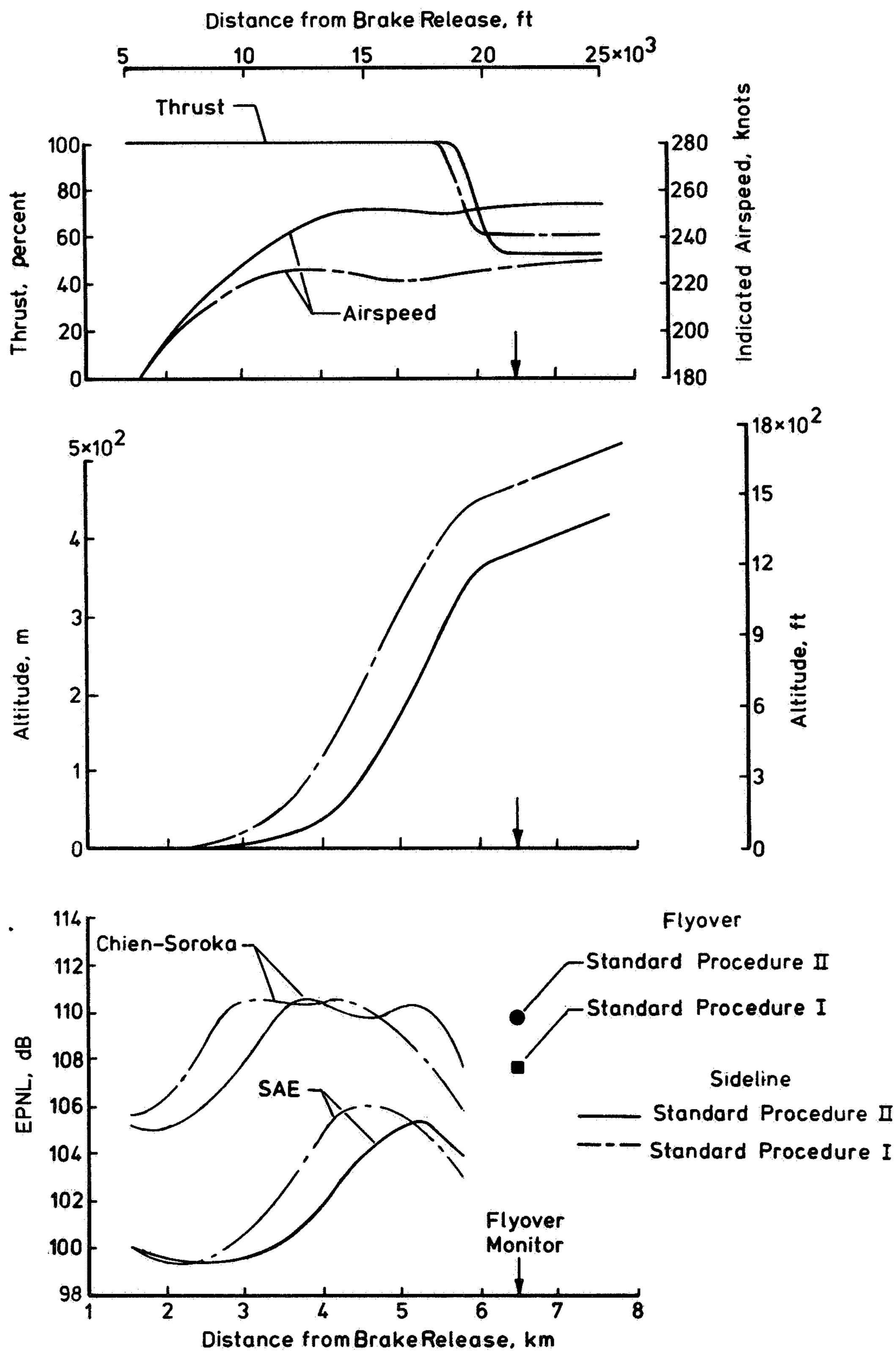
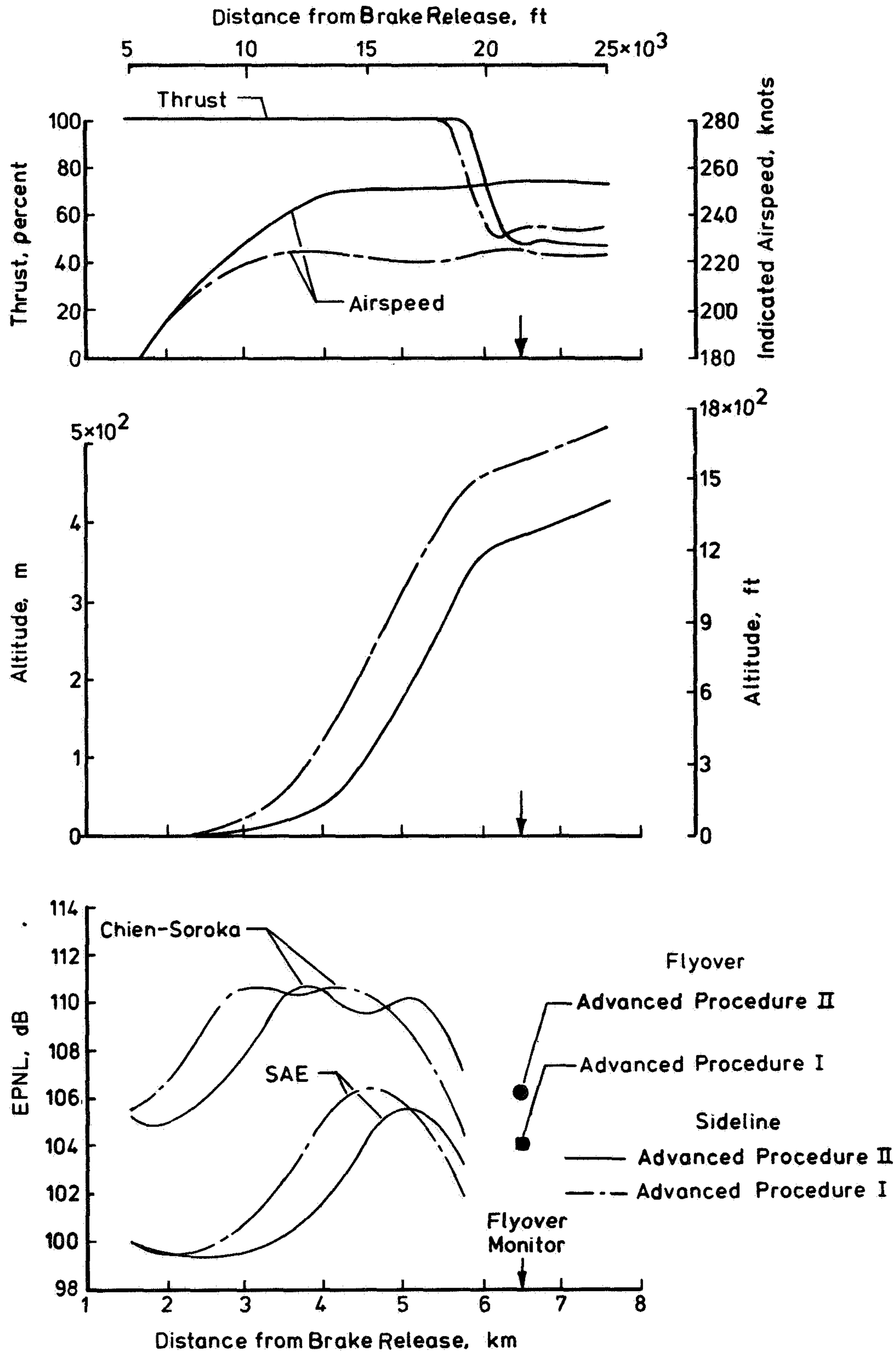


Figure 4.- Noise measurement locations for takeoff and landing. Sideline noise is measured where noise level after lift-off is greatest.



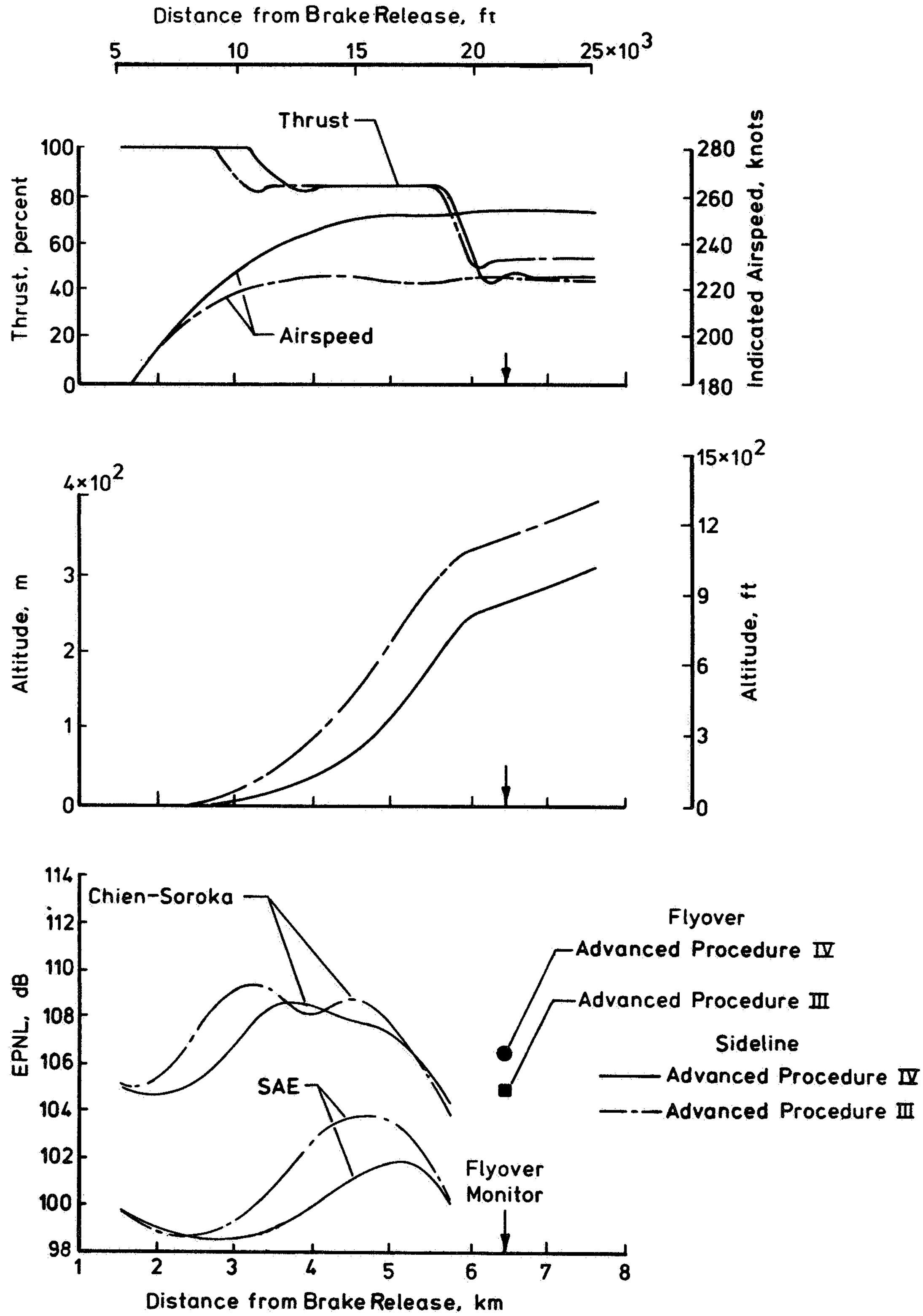
(a) Standard procedures I and II.

Figure 5.- Takeoff profiles and sideline flyover noise.
Jet noise only.



(b) Advanced procedures I and II.

Figure 5.- Continued.



(c) Advanced procedures III and IV.

Figure 5.- Concluded.

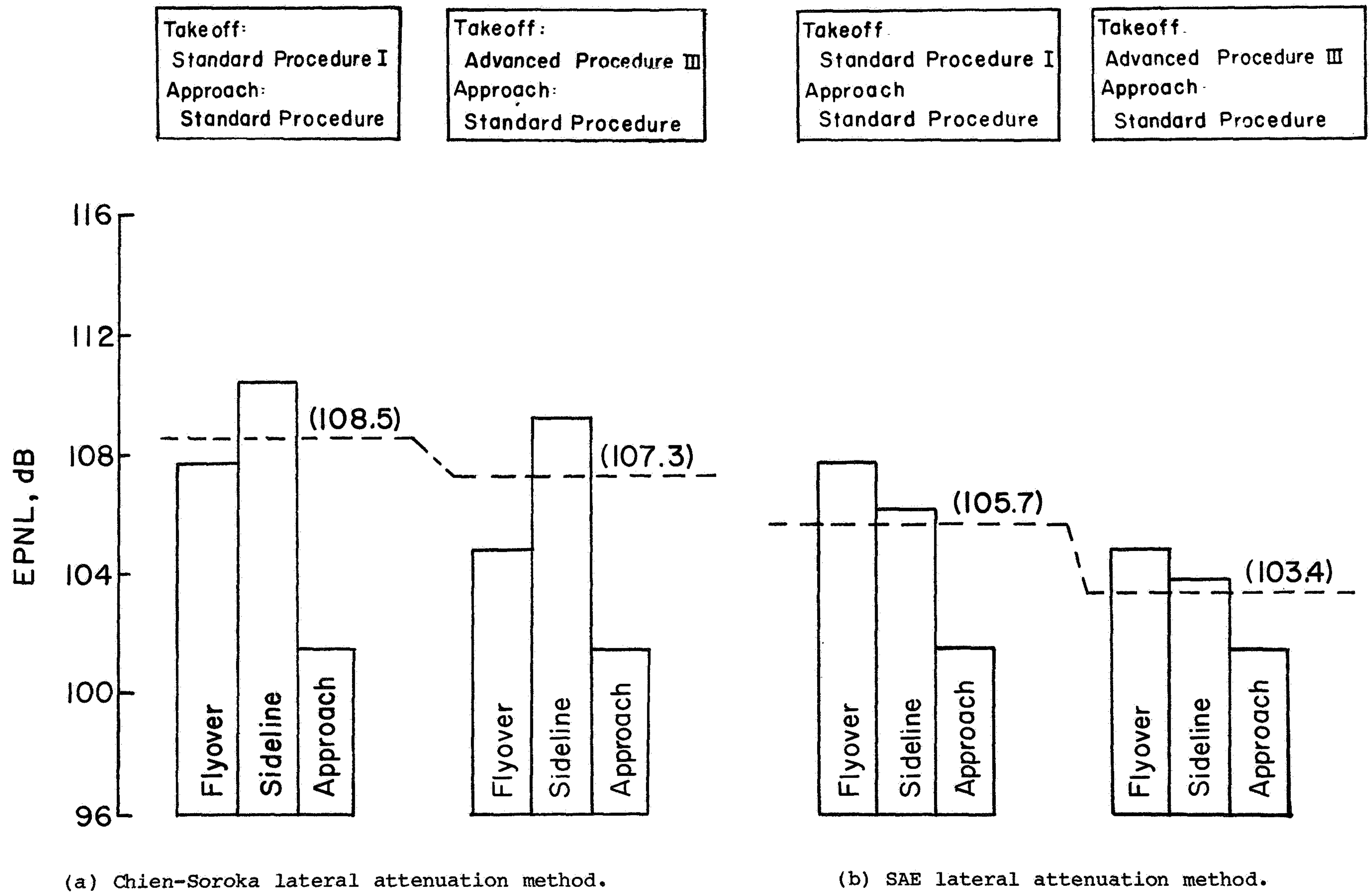
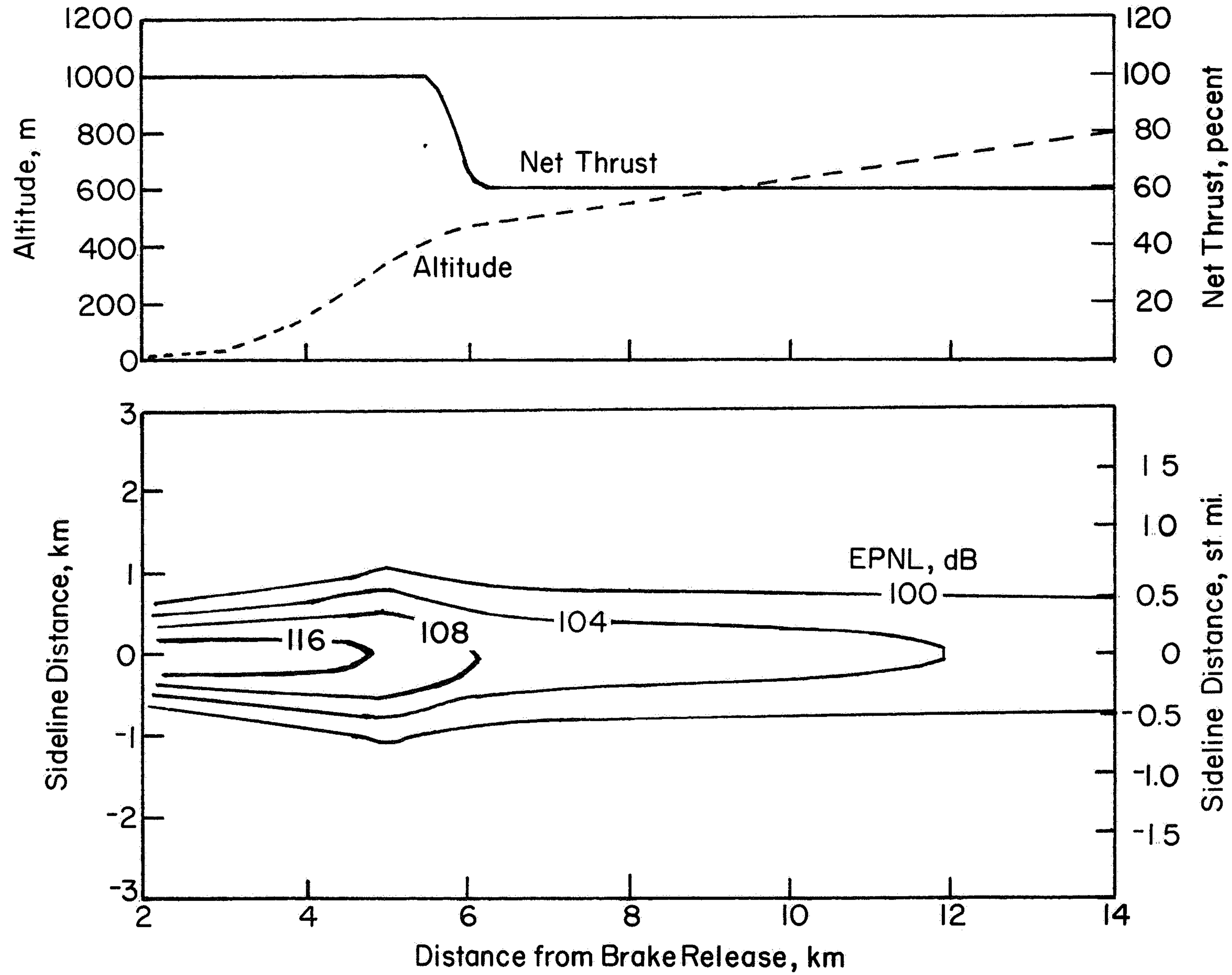
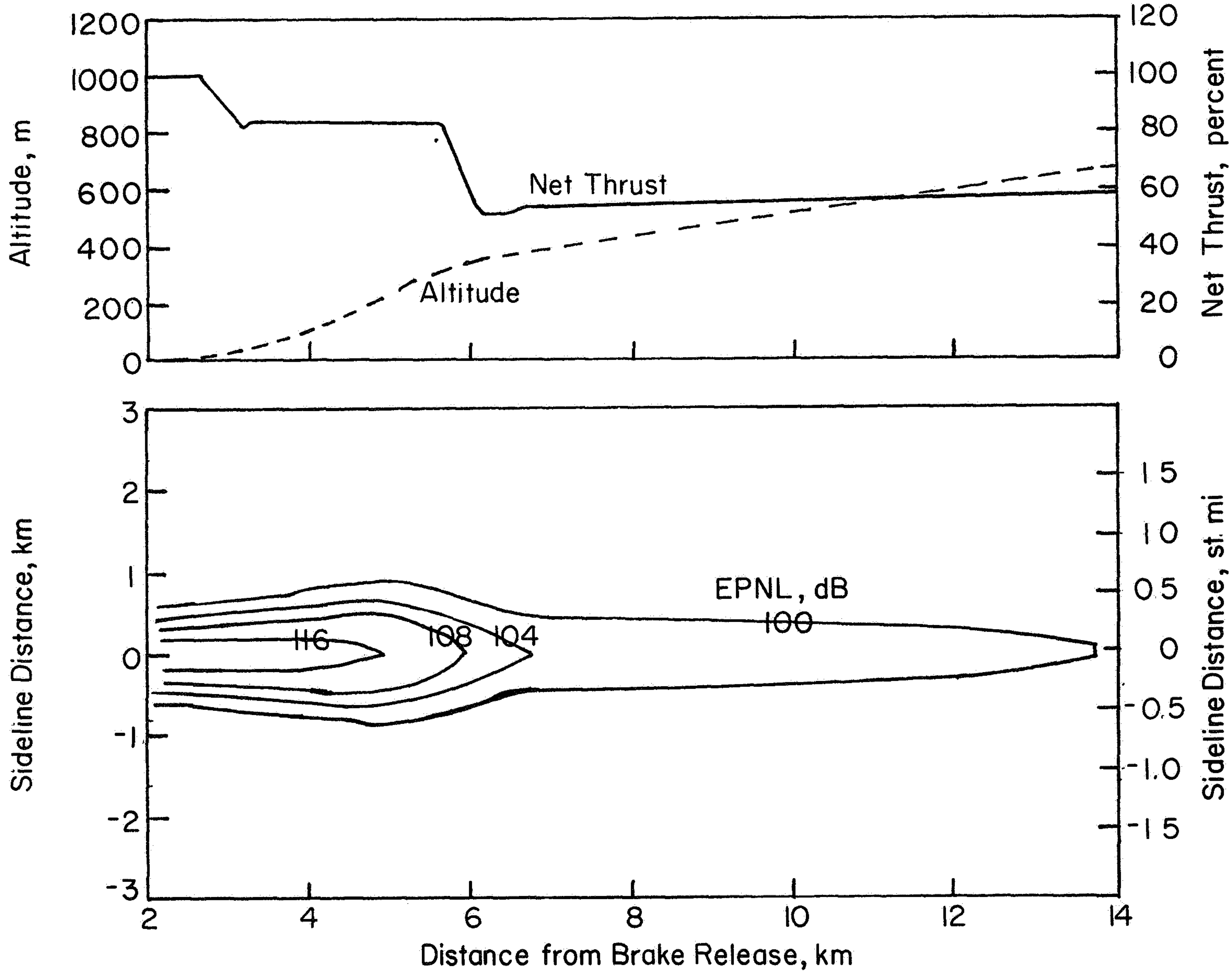


Figure 6.- Jet noise levels for some conditions and procedures. Numbers in parentheses indicate traded noise levels.



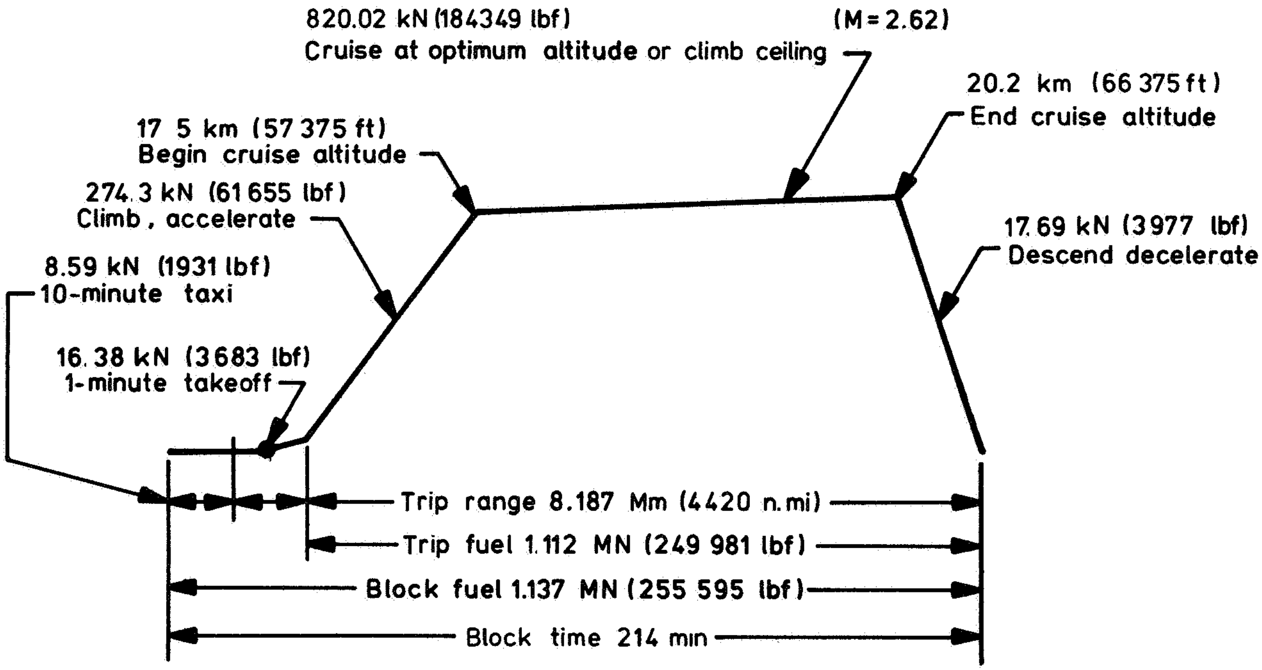
(a) Standard procedure I.

Figure 7.- Takeoff noise contours, net thrust, and altitude profiles. Jet noise only; SAE lateral attenuation method.



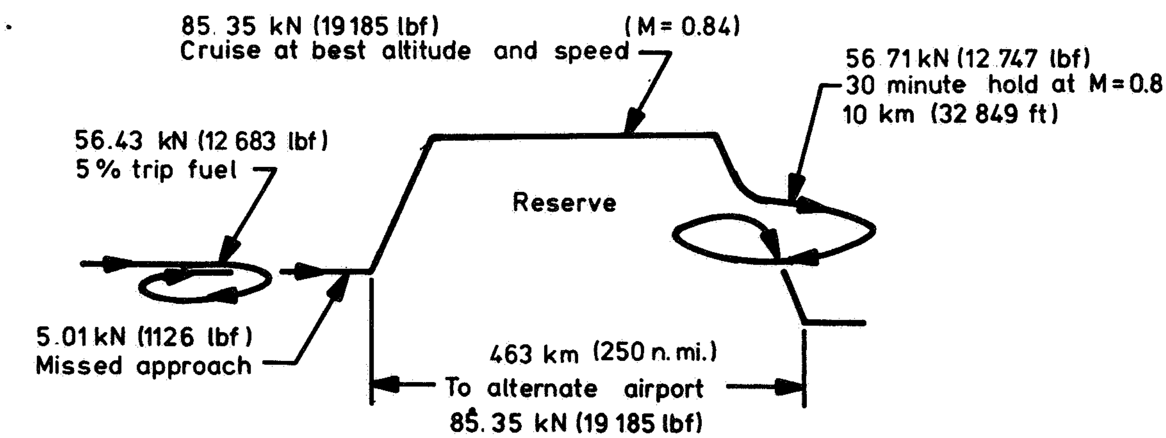
(b) Advanced procedure III.

Figure 7.- Concluded.



Note. CAB range = trip range minus traffic allowance as specified for supersonic aircraft

(a) Primary mission.



(b) Reserve allowance mission.

Figure 8.- Mission profile and fuel weights associated with each segment.

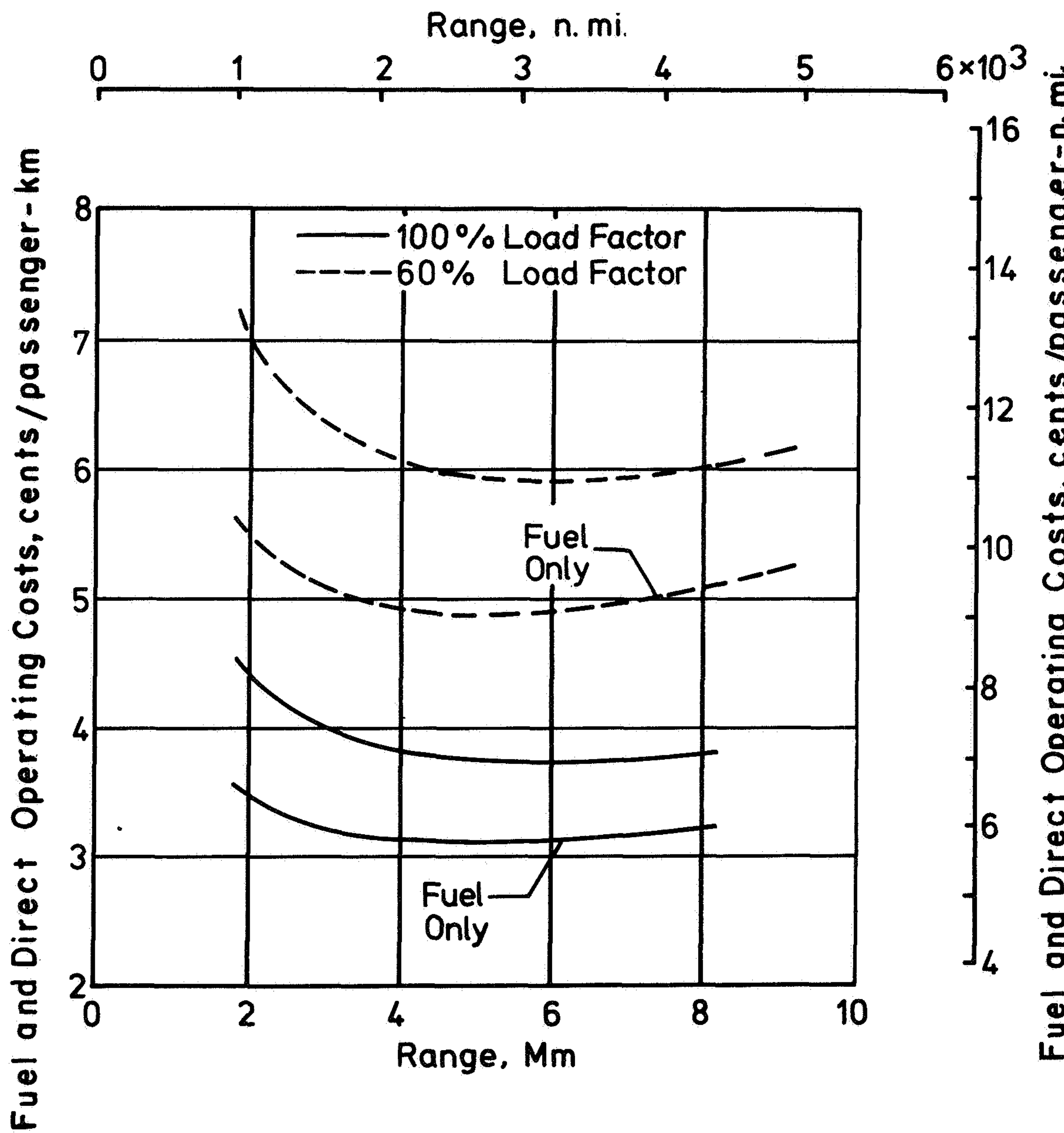


Figure 9.- Fuel and direct operating costs as function of range and passenger load factor.

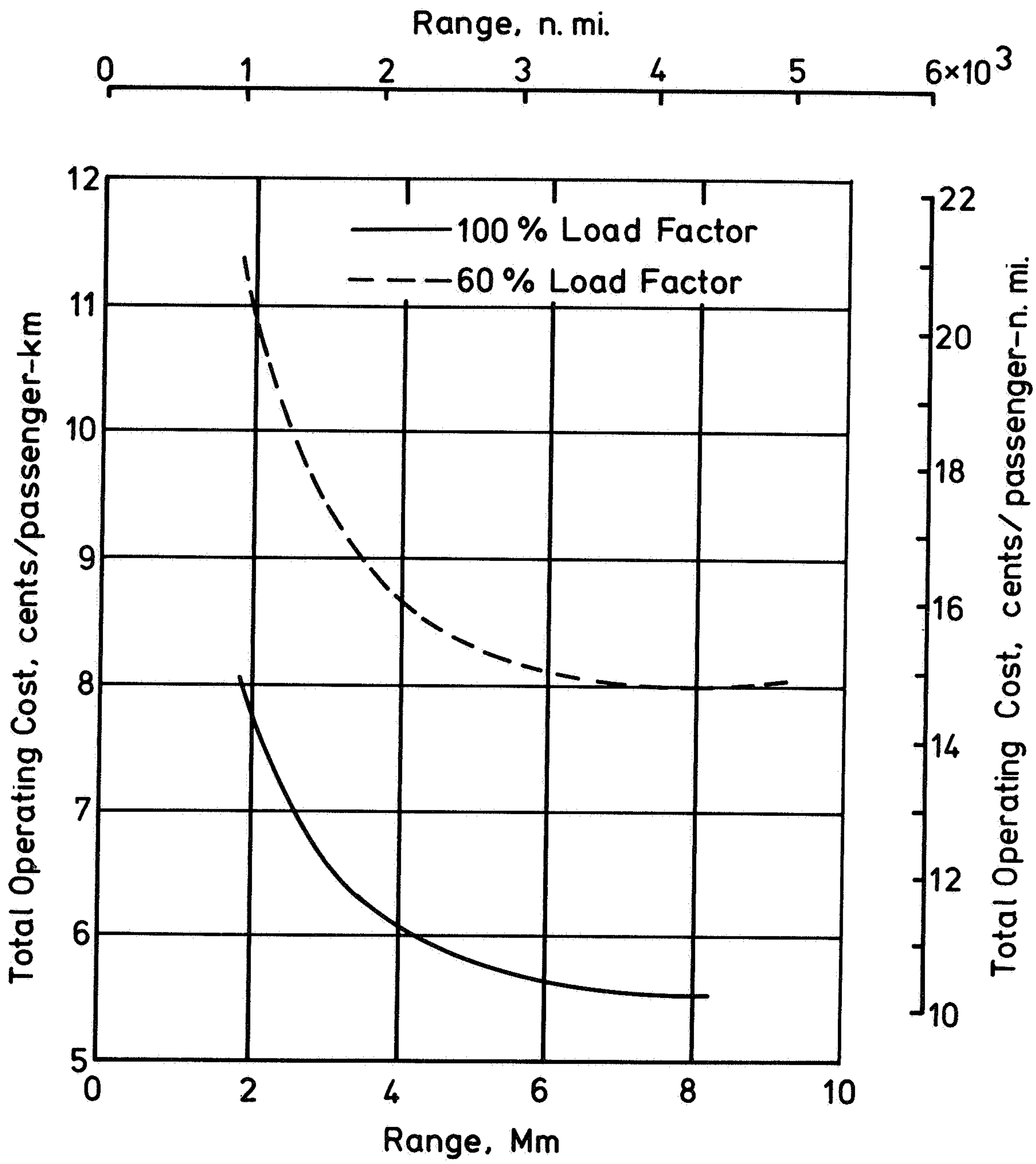


Figure 10.- Total operating cost as function of range and passenger load factor.

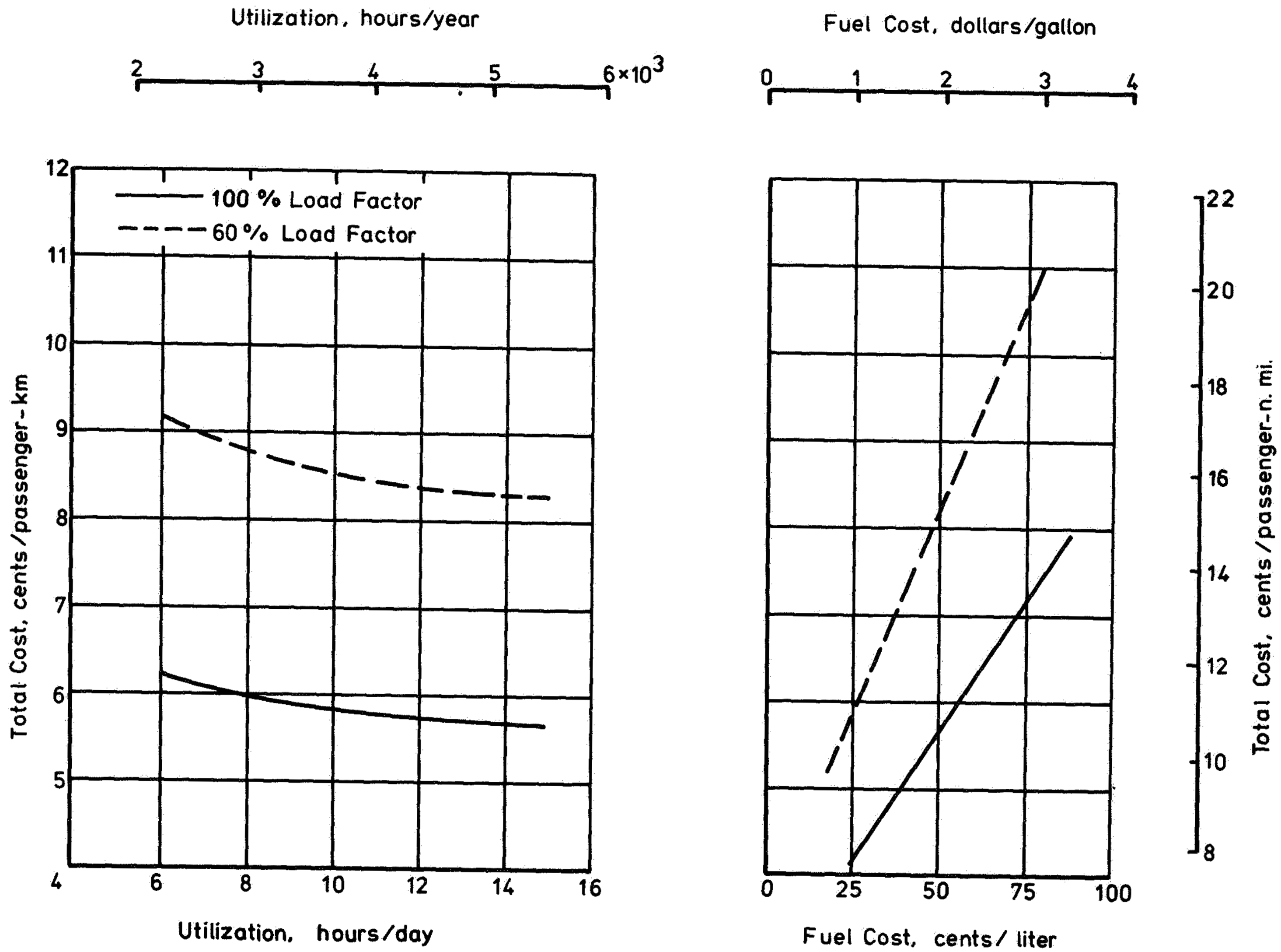


Figure 11.- Sensitivity of total cost to utilization and fuel cost for design range.

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16. Abstract

Noise and economic characteristics were obtained for an advanced supersonic transport concept that utilized wing-body blending, a double-bypass variable-cycle engine, superplastically formed and diffusion-bonded titanium in both the primary and secondary structures, and an alternative interior arrangement that provides increased seating capacity. The configuration has a cruise Mach number of 2.62, provisions for 290 passengers, a mission range of 8.19 Mm (4423 n.mi.), and an average operating cruise lift-drag ratio of 9.23. Advanced operating procedures, which have the potential to reduce airport-community noise, were explored by using a simulator. Traded jet noise levels of 105.7 and 103.4 EPNdB were obtained by using standard and advanced takeoff operational procedures, respectively. A new method for predicting lateral attenuation was utilized in obtaining these jet noise levels. Therefore, if jet noise is considered representative of total noise, it appears that a supersonic transport could achieve the noise levels required by Federal Aviation Regulations, part 36, stage 2. Direct and total operating costs were calculated. Total operating costs of approximately 5.5 cents/passenger-km (10 cents/passenger-n.mi.) and a fuel efficiency of 16.4 seat-km/L (33.6 seat-n.mi./gal) were predicted for the design range and load factor of 100 percent.

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